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An Energy-Efficient Min-Max Optimization with RSA Security in Wireless Sensor Networks

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ABSTRACT

A Novel Energy-efficient Min-max Optimization (NEMO) is proposed to improve the data delivery performance and provide security in WSN. The NEMO scheme is applied in the virtual grid environment to periodically collect the data from source node to the mobile sink through the cell headers. Here the movement of sink is in controlled fashion and collects the data from the border line cell headers. For efficient data delivery Fruit Fly Optimization (FFO) algorithm is applied here to find the best path by using the fitness value calculated between the nodes based on the distance. The optimal path is chosen by first calculating the minimum hop count paths and then finds the maximum of total fitness value along those paths. In that way best path is selected by considering the shortest path which improves the data delivery performance and also it minimizes the energy consumption. The proposed scheme enables the sensor nodes to maintain the optimal path towards the latest location of mobile sink by using the FFO algorithm which leads to maximize the network lifetime in wireless sensor networks. RSA digital signature is used to provide the security between the intermediate nodes during the data delivery. The source node generates the keys and broadcast it to all other nodes in the network. Source node signs the data using its private key and the intermediate nodes verifies the data using the source's public key which is already broadcasted by the source node. If the data is valid then it forwards to the next intermediate nodes and till the sink node gets the data, forwarding takes place. Else the data packets are dropped and inform that node as misbehaving node and the source chooses the next best path without having that misbehaving node in the path..

KEYWORDS: *Energy, optimization, data delivery, FFO, fitness value, RSA, Intermediate nodes, Misbehaving node*

I. Introduction

A. Wireless Sensor Network

Wireless sensor network is a group of specialized transducers with a communication infrastructure intended to monitor and record conditions at diverse locations. Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. The application of wireless sensor networks to reduce the effort of human in various environments such as disaster management, intelligent transport system, battle field, healthcare environment and so on. Especially for sink mobility sensor nodes deployed at various points on interest (junctions, car parks, area susceptible to falling rocks) can provide early warning to drivers (mobile sink) in intelligent transport system. The architecture diagram for sensor network is shown in Figure A.1.

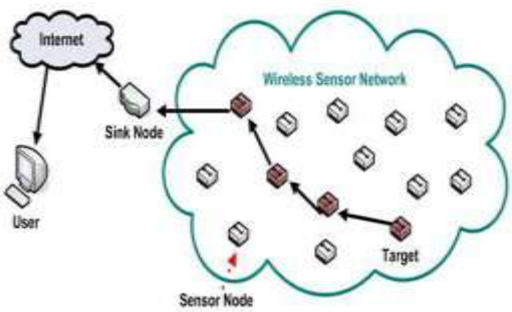

Figure A.1 Sensor network architecture

B. *Energy Consumption of Sensor Node*

The sensor nodes operate in the three modes: sensing, computing and communications. The sensing unit is entrusted with the responsibility to detect the physical characteristics of the environment and an energy consumption that varies with the hardware nature and applications [1]. The communication unit consists of a short-range circuit which performs the transmission and reception tasks [2]. Communication energy contributes to data forwarding and it is determined by the transmission range that increases with the signal propagation in an exponential way.

The energy consumption model includes the five states:

- Acquisition: The acquisition state includes sensing, conversion, pre-processing and eventually storage of these data
- Transmission: The transmission state includes processing, packet forming, encoding, framing, queuing and base band adapting to circuits
- Reception: This state is responsible for low noise amplification, down converter oscillator, filtering, detection, decoding, error detection, address checking and random reception
- Listen: The listen state is similar to a reception and involves the processes of low noise amplification, down convertor oscillator, filtering and terminates at detection
- Sleep: The sleep state expends less energy as compared to the other state

The general approaches to energy conservation in sensor nodes are as follows:

- Duty cycle
- Data driven
- Mobility

B.1 Duty Cycle

Duty cycle is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the sleep mode whenever communication is not required. Duty cycle is defined as the fraction of time nodes are active during their lifetime. As sensor nodes perform a cooperative task, they need to coordinate their sleep times. A sleep scheduling algorithm thus accompanies any duty cycling scheme. It is typically a distributed algorithm based on which sensor nodes decide when to do transition from active to sleep and vice versa.

B.2 Data Driven

Data driven techniques are designed to reduce the amount of sampled data by keeping the sensing accuracy within an acceptable level for the application. Data reduction schemes address the case of unneeded samples, while energy-efficient data acquisition schemes are mainly aimed at reducing the energy spent by the sensing subsystem. However, some of them can reduce the energy spent in communication as well. The techniques aim at reducing the amount of data to be delivered to the sink node.

B.3 Mobility

Mobility is also useful for reducing energy consumption. Packets coming from sensor nodes traverse the network towards the sink by following a multi-hop path [3]. When the sink is static a few paths can be more loaded than others, depending on the network topology and packet generation rates at the sources [4]. The nodes closer to the sink also have to relay more packets so that they are subject to premature energy depletion, even when techniques for energy conservation are applied [5]. The traffic flow can be altered if a designated mobile device makes itself responsible for data collection.

C. *Fruit Fly Optimization*

Fruit Fly Optimization is an emerging method for understanding universal optimization predicated on the foraging comportment of the fruit fly [6-8]. The sensory perception of the fruit fly is better than that of other species, especially the sense of smell and vision [9]. The olfactory organ of a fruit fly can collect sundry smells from the air, and even a victuals source 40 km away. Afterwards, the fruit fly flies in the food, uses its acute vision to find the victuals and where its fellows accumulate, and then it flies in that direction, as shown in Figure B.2

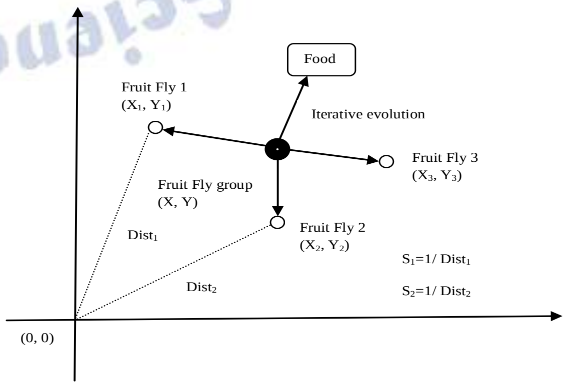

Figure B.2 Schematic diagram of fruit fly swarm

D. RSA Security Protocol

RSA security protocol stands for the Rivest, Shamir and Adleman, who are the creator of the RSA. RSA is an asymmetric-key security protocol as it uses two different keys for its encryption and decryption purpose. It is the most popular and proven asymmetric key cryptography algorithm. It generates two keys (private key and public key). The private key is secret to the user and public key is known to others who want to communicate with the user. For this reason it is also known as public-key cryptography. It is the first algorithm known to be suitable for signing as well as encryption, and was one of the first great advances in public key cryptography. RSA is widely used in electronic commerce protocols, and is believed to be secure given sufficiently long keys and the use of up-to-date implementations.

II. RELATED WORKS

Oh et al [10] proposed a communication protocol to support sink mobility without global position information. To reduce the number of cell headers, we consider multi-hop clusters. Also, to avoid the location registration of a mobile sink to the whole cell headers, we use a rendezvous cell header on which queries of the mobile sink and reporting data of a source node meet. However, such a manner also has a data detour problem that the source node sends data packets to the mobile sink via the rendezvous cell header. Thus, a scheme is presented to find a path with less hop counts between cell headers where the source node and the mobile sink are located in. Simulation results show that the proposed protocol is superior to the existing protocols in terms of the control overhead and the data delivery hop counts.

Erman et al [11] addressed the data delivery to mobile sink and source event dynamic conditions hexagonal grid structure is constructed. Nodes send data which forwards towards the center cell from the nearest border line. The data will be stored and replicated at the nodes which are on the border line. Sink sends queries towards the center cell and after reaching particular border line node that consists data it sends in reverse path. When sink moves, it informs to both border nodes and center nodes along the route. The border line cells and center cells result in more energy dissipation.

Kumar Saurabh et al [12] protected the security of the sensed data in wireless sensor networks. The RSA algorithm is used as a digital signature authentication in the field of security basically works on deciding encryption variable. In this also the basic concept is to decide a description variable and then decide the description variable using same encryption variable. It is a secure and fast cryptographic system. The major effort will be applied to the RSA encryption technique in order to make node authenticated as well as to secure data while dealing with aggregation.

Chen et al [13] discussed about the virtual circles and straight lines are used for virtual structure construction. The virtual backbone network is formed by a set of cluster head along with straight lines and virtual circles. For data collection sink moves around with straight lines and virtual circles. For data collection sink moves around the sensor field and communicates with cluster heads, which are on the border. The cluster heads minimize route readjustment by following a set of rules. The cluster head depletes its energy, fast because it is placed at the center of the sensor field and also mainly involve in route readjustment.

Hazim Iscan et al [14] studied a fruit fly optimization algorithm based on foraging behavior of the real fruit flies. In order to find the optimum solution for an optimization problem, fixed parameters are obtained as a result of manual test in the fruit fly algorithm. This method is aimed to find the optimum solution by analyzing the constant parameter concerning the direction of the algorithm instead of manual defining on initialization stage. The study shows an automated approach for finding the related parameter by utilizing a grid search algorithm.

Abdo Saif Mohammed et al [15] improved low energy aware protocol with a novel algorithm to select cluster heads with highest and balanced energy in wireless sensor networks with an authentication protocol to protect our previous work and network from attackers. This method uses RSA algorithms to secure the packet during send to both cluster heads and base station and it prolongs the lifetime of wireless sensor networks.

Huan Zhao et al [16] presented a novel sensor deployment scheme based on a fruit fly algorithm to improve the coverage rate. Each fruit fly represents a solution for sensor deployment independently, and they are given the random direction and distance for finding food using osphresis. Then find the fruit fly with the highest smell concentration, judgment value from the fruit fly group and keep its positions, and then the fruit fly group will fly towards that position by using their sensitive vision.

Khan et al [17] proposed a virtual grid of uniform size cells is formed by partitioning the sensor field and the nodes closest to the center of the cell are appointed as cell headers. Nodes other than cell headers report data to cell headers. Cell headers adjust the routes based on the propagation rules for sink mobility. Mobile sink moves around the sensor field to collect data periodically. The disadvantage of this scheme is certain cell headers take long route to deliver the data to mobile sink this increases energy consumption.

III. Existing System

Exploiting the sink's mobility helps to prolong the network lifetime, thereby alleviating energy-hole problems. In the virtual infrastructure based data dissemination schemes, to minimize the energy consumption of each individual node only a set of designated nodes scattered in the sensor field is responsible to keep track of sink's locations such designated nodes gather the observed data from the nodes in their vicinity during the absence of the sink and then proactively or reactively report data to the mobile sink. In order to minimize the route reconstruction cost only a limited number of cell-headers previous originating cell header and downstream of originating cell header take part in the routes re-adjustment process. Virtual grid based dynamic route readjustment scheme gave minimum route readjustment cost, but it did not consider the distance priority based routing and which results in more delay of packet delivery. For that in proposed work fruit fly optimization is used to minimize the delay in packet transmission by considering the shortest path routing in the network.

IV. Proposed System

A. *Proposed System Architecture*

A Novel Energy-efficient Min-max Optimization (NEMO) scheme is used to provide the energy efficient data delivery by applying the Fruit Fly Optimization (FFO) algorithm. FFO have two main functions called vision and smell function. Vision function is related to the calculation of minimum hop count value and the smell function is related to the maximum value of Fitness Function (FF). Rivest Shamir and Adleman (RSA) security protocol is used for the message authentication between the sources and sink node.

The proposed scheme enables sensor nodes to maintain nearly optimal routes to the latest location of a Mobile Sink (MS) with minimal network overhead. It partitions the sensor field in a virtual grid of equal sized cells and constructs a virtual backbone network comprised of all the Cell Header (CH). Nodes close to the center of the cells are appointed as CHs, which are responsible for data collection from member nodes within the cell and delivering the data to the MS using the virtual backbone network.

The goal behind such virtual structure construction is to minimize the routes re-adjustment cost due to sink mobility so that the observed data is delivered to the MS in an energy efficient way. In addition, it also sets up communication routes such that the end-to-end delay and energy cost is minimized in the data delivery phase to the MS. The MS moves along the periphery of the sensor field and communicates with the border CHs for data collection. The routes re-adjustment process is governed by a set of rules to dynamically cope with the sink mobility.

Using this scheme, only a subset of the CHs needs to take part in re-adjusting their routes to the latest location of the MS thereby reducing the communication cost. Simulation results reveal decreased energy consumption and faster convergence when compared to other state-of-the art.

B. *Module Description*

The modules of the proposed system are classified as:

- Virtual Structure Construction
- Fruit Fly Optimization
- RSA Security

B.1 Virtual Structure Construction

In the proposed scheme, the virtual grid structure is formed by taking a number of sensor nodes in the field and it is partitioned into several uniform sized cells and explained as follows

B.1.1 Network Partitioning

The partitioning of sensor field is taken because of uniform workload on the part of CH nodes which expand the network lifetime. Cell size is partitioned from sensor network such that it should satisfy the range in between sensor node minimum range and sensor node maximum range as mentioned in the Table B.1

Table B.1 Network partition

No. of nodes (N)	Minimum and Maximum Range for CH Selection	No. of CH (K)
100	1 < N×0.05 ≤ 6	4
200	6 < N×0.05 ≤ 12	9
300	12 < N×0.05 ≤ 20	16

B.1.2 CH Election

The proposed scheme elects CH in every cell, i.e. the node which is closest to the midpoint of the cell. The total number of nodes computes the midpoints of all the cells by the sensor field's dimension knowledge. In election process to reduce communication cost, the nodes whose distance to the midpoint of the cell having less threshold will only take part in the election. The threshold distance may increase during the election process if no node is found within the threshold distance. This election strategy helps in energy conservation and also elects CH at the appropriate position within the cell.

B.1.3 Establishing Adjacencies

After every CH election, every CH shares its status within the cell and slightly outside the cell boundary. Nodes associate themselves to the closest one when it receives notification from more than one CH. Nodes when receive multiple notifications it shares information to primary CH about the secondary CH. In this way, neighboring CHs form adjacencies using gateway nodes is shown in the Figure B.2.

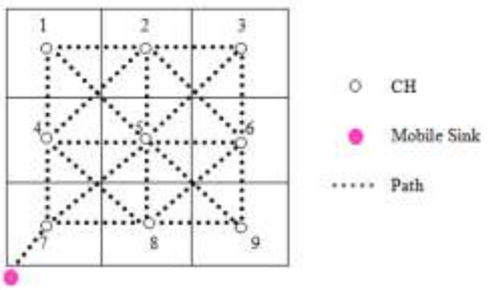

Figure B.2 Virtual structure after establishing adjacencies

B.2. Fruit Fly Optimization

FFO is one of the swarm optimization algorithm based on the foraging behavior of fruit fly using the vision and smell function. FFO is mainly used to select the optimal path between the sink and source node. Initially it calculates the distance between the neighbors CH's and then takes the reciprocal of that value as the decision value. After that for each and every possible path between the source and sink for a particular position of mobile sink FF is calculated.

FF is the sum of the decision value along the particular path and then it applies the two main functions of fruit flies to the path. From the entire possible path based on the vision function, it only selects the minimum hop count path and then by applying the smell function it calculates the optimal path based on the FF. Figure 4.3 shows the calculation of decisive value among the neighbor CH's.

Procedure for FFO

Step1: Each and every CH calculates the decision value among the neighbor CH's using equations 4.1 and 4.2. The decision value is the reciprocal of the distance calculated between the current CH and neighbor CH's

$$\mathrm{Dist_i} = \sqrt{(X_i^2 + Y_i^2)} \quad (4.1)$$

$$S_i = \frac{1}{\mathrm{Dist_i}} \quad (4.2)$$

Step2: For each and every location of mobile sink the FF is calculated. Initially the location of MS is at (0, 0)

Step3: Based on the particular location of mobile sink, each and every CH calculates the FF for its entire possible path to the current location of mobile sink

FF=Sum (decision value) [along all the paths]

Step4: Vision function is used to calculate the minimum hop count value from all possible paths from source to sink

[Best Vision Possible Path] = min (hop count)

Step5: After the vision function, smell function is calculated based on the maximum fitness function for the paths and then decide that path as the best optimal path

[Best Smell Optimal Path] = max (FF)

Consider the below example in Figure B.4 shows the optimal path selection from the possible paths using FFO with help of vision and smell function at each and every location of MS. Table B.2 shows the selection of optimal path from

possible paths using FFO based on the FF value for all possible paths.

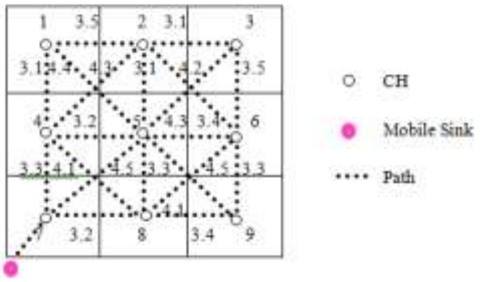

Figure B.3 Calculation of decision value among the neighbor nodes

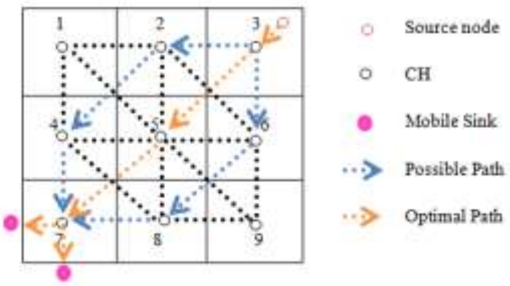

Figure B.4.1 Optimal path selections at 1st and 12th position of MS

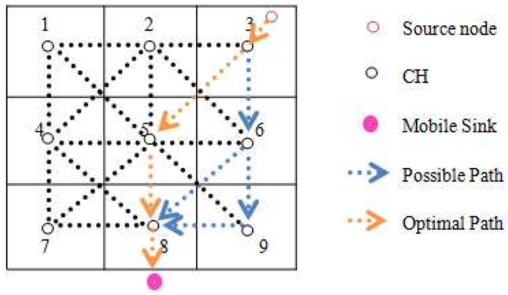

Figure B.4.2 Optimal path selections at 2nd position of MS

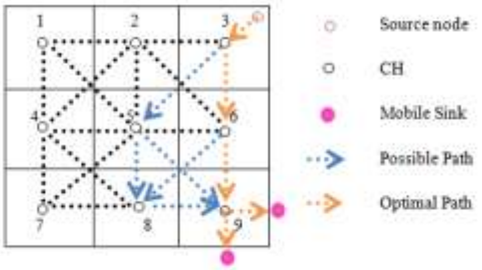

Figure B.4.3 Optimal path selections at 3rd and 4th position of MS

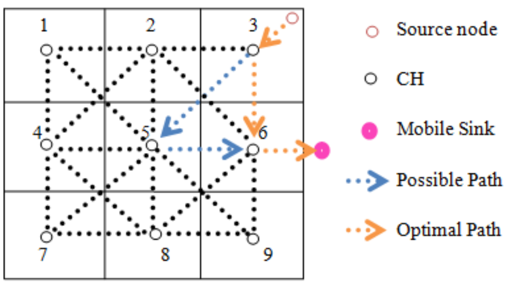

Figure B.4.4 Optimal path selections at 5th position of MS

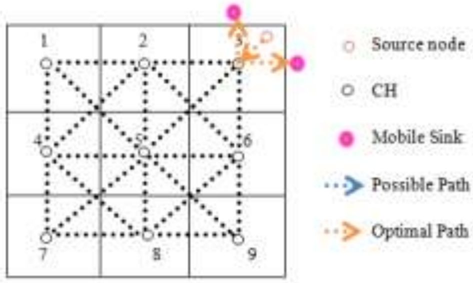

Figure B.4.5 Optimal path selections at 6th and 7th position of MS

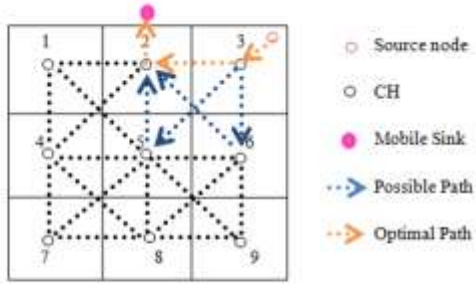

Figure B.4.6 Optimal path selections at 8th position of MS

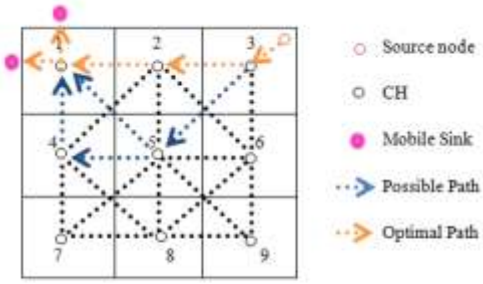

Figure B.4.7 Optimal path selections at 9th and 10th position of MS

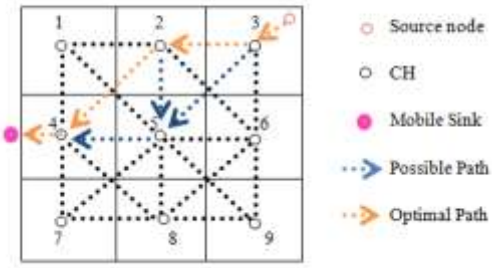

Figure B.4.8 Optimal path selections at 11th position of MS

RSA Security

In the proposed system, RSA security protocol uses the signature and verification algorithm to provide the secure communication between the sink and source node in the networks. Initially the source node generates two different large distinct prime numbers p and q. Then using these two values it generates a public key suite (e, n) and a private key suite (d, n) and then broadcasts its public key in the network of its range. The entire cluster head stores the public key of the source node in its memory.

After sensing data the source node signs the message using the signature algorithm and then it forwards the message along with the signature value to the Corresponding Cell Header (CCH) and then it verifies the received message with the verification algorithm, if the message is valid it then forwards the packet to next CH or else it informs the source node that the particular CH as misbehaving node and then the source node selects the next optimal path using FFO without having that misbehaving node in the path.

Likewise it repeats the process until it reaches the sink node. In this way a secure communication between the sink and the source node is preserved.

Procedure for RSA

Key Generation: Source node generates key [public (e), private (d)] and broadcast its public key (e, n) to all other nodes

Signature: Source signs the message M using signature algorithm ($S=M^d$ mod n) with the help of source's private key d and generates the sign S then it forwards (S, M) to the source's CCH

Verification: CCH verifies the original message (M) using verification algorithm ($M'=S^e$ mod n) using source's public key e which generates the verified message (M′)

If (M′ == M)

- It forwards (M,S) to intermediate CH along the path
- It repeats the same process till it reaches the sink node

else

- It drops the packet and informs that the particular node as misbehaving node
- Source node chooses the next optimal path without having that misbehaving node

PARAMETER EVALUATION

Novel Energy efficient Min max Optimization (NEMO) scheme is compared with Virtual Grid based Dynamic Route Adjustment (VGDRA) were a common feature between them is the use of a virtual infrastructure for network operation. Here three different criteria to evaluate the performance of VGDRA against VGDRA scheme. The following are the parameters which are taken into account for comparison:

- Energy
- Packet Delivery Ratio
- Delay

Energy:

Figure A.1 represents the comparison between Nodes and Energy. Nodes using NEMO scheme incur less energy compared to the VGDRA scheme because of taking the shortest path between the source and sink. The NEMO scheme, using the average node energy consumption in reconstructing the data delivery routes to the latest location of mobile sink.

The values of power consumption are listed in Table A.1. Power consumption of the proposed scheme consumes minimum compared to the VGDRA scheme. For the different number of nodes the proposed scheme minimizes energy by 9-12% when compared to the existing approach.

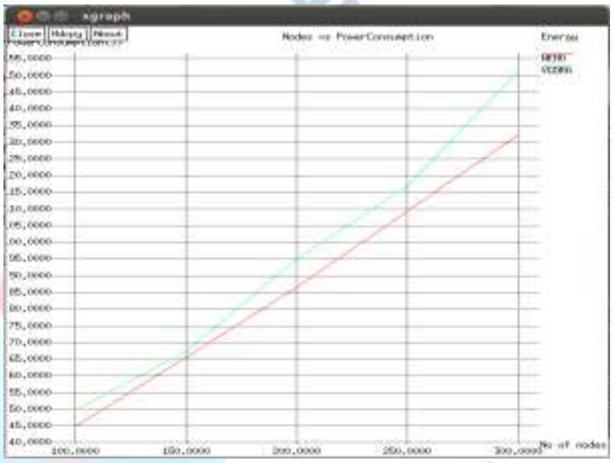

Figure A.1 Comparing the energy efficiency for different network sizes

Table 5.1 Nodes Vs Energy

Number of Nodes	Power Consumption (Joule)	
	VGDRA	NEMO
100	49.68	44.76
200	95.19	86.41
300	151.24	132.18

Packet delivery ratio

Figure 5.2 indicates the packet delivery performance. The packet delivery ratio can be calculated as the ratio between transmitted and received for overall packets. NEMO algorithm and VGDRA are compared with node variation. When sensor nodes increased from 100 to 300 nodes in the environment, the packet delivery ratio is decreased in both the algorithms. But NEMO scheme has better packet delivery ratio compared to VGDRA scheme.

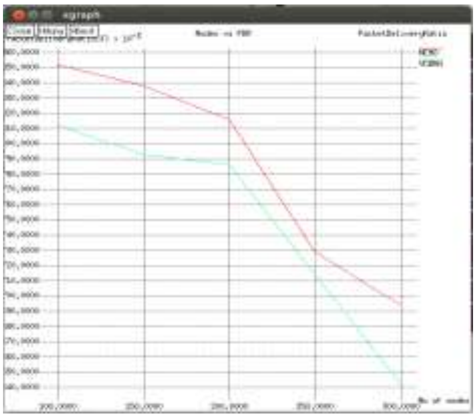

Figure A.2 Comparing the packet delivery for different network sizes

Table A.2 Nodes Vs Packet delivery ratio

Number of Nodes	Packet Delivery Ratio (%)	
	VGDRA	NEMO
100	0.812	0.852
200	0.786	0.816
300	0.642	0.694

The values of the packet delivery ratio are listed in Table 5.2. The packet delivery ratio is maximized compared to the VGDRA scheme. For the different number of nodes the proposed scheme maximizes the packet delivery ratio by 4-8% when compared to the existing approach.

Delay

The delay time is an indirect reflection of the data delivery efficiency as the more promptly the nodes come to know about the latest location of a mobile sink, the most efficient routes they can select in disseminating the sensed data. Figure A.3 represents the delay time of the NEMO is minimum compared to VGDRA when the sink is moving at a speed of 10 m/s.

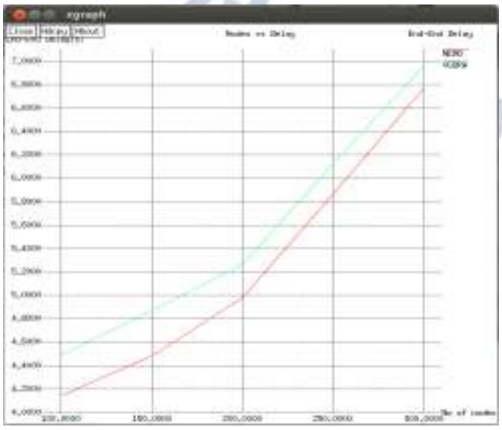

Figure 5.3 Comparing the delay time for different network sizes

Table 5.3 Nodes Vs End to end delay

Number of Nodes	End to End Delay (s)	
	VGDRA	NEMO
100	4.49	4.14
200	5.26	4.98
300	6.96	6.77

The values for the delay time are listed in Table A.3. The delay time is minimum compared to the VGDRA scheme. For the different number of nodes the proposed scheme minimizes the delay by 3-7% when compared to the existing approach.

V. Conclusion

A novel Fruit Fly Optimization (FFO) with secure data transmission in wireless sensor network scheme used for energy efficient data delivery and also to provide message authentication between the source and the sink communication. For an energy efficient data delivery, fruit fly optimization algorithm uses the vision and smell function to calculate the optimal path based on shortest path routing. The FFO used to achieve minimum delay with more packet delivery ration compared to the previous work and which leads to less energy consumption in the network. In order to provide message authentication between the source and the sink, The RSA security protocol is used. Data communication takes place between the source and sink and it is achieved only through the intermediate cell header. There is a possibility that those nodes can also be act as a misbehaving node in the network. In such cases, RSA identifies those misbehaving node and chooses the next optimal path without having that misbehaving node using the fruit fly optimization algorithm. As a result, it achieves secured energy efficient data delivery in wireless sensor networks. In future, analyze the performance of the proposed scheme at different sink's speeds and different data generation rates of the sensor nodes. The proposed scheme offers a lightweight solution and does not impose many constraints on part of the resource constrained sensor motes, yet its practical implementation on real hardware needs to be confirmed.

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